

Spatial distribution of the Tawny Fish Owl *Ketupa flavipes* shaped by natural and man-made factors in Taiwan

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This study investigated the distribution of the Tawny Fish Owl *Ketupa flavipes*, a rare top predator in Taiwan, and examined natural and man-made factors that affect it. Records of Tawny Fish Owls from 1993 to 2006 were compiled from field studies, literature surveys, museum notes and specimens, and interviews with researchers, birdwatchers and indigenous hunters. In total, 91 Tawny Fish Owl territories were identified, widely distributed along mountain streams in the Central Mountain Range between 48 and 2,407 m—more than half of them were below 700 m. The upper altitudinal range of the owls is probably limited by food availability and stream size. Territories were on average 431 m higher on the west side of the Central Mountain Range than on the east. Habitat selection analysis further indicated that, in proportion to the land area available, the Tawny Fish Owl was absent from areas below 500 m. This is apparently due to extensive deforestation of lowlands for agriculture and urbanisation on the west side of the island. It is recommended that a protected area be established in the north-east part of Taiwan, to preserve the remaining lowland streams and riparian forests still inhabited by the species.

INTRODUCTION

Fish owls are top predators in freshwater food chains and are important indicator species for healthy stream ecosystems (Duncan 2003, Wu *et al.* 2006). The Tawny Fish Owl *Ketupa flavipes* is widely distributed in the Himalayas, eastern Indochina, south China and Taiwan (Voous 1988, Marks *et al.* 1999). It reaches 58 cm in body length (Sun 1996), making it one of the largest raptors within its range. However, it is so rarely observed in the wild that it is considered to be rare over most of its range (Marks *et al.* 1999). It is currently listed in CITES Appendix II (UNEP-WCMC 2009).

The species was first reported from Taiwan by Kuroda (1916). Since then its natural history has remained poorly known (Voous 1988). In 1989, when the Wildlife Conservation Law was first implemented in Taiwan, the Tawny Fish Owl was listed as an Endangered Species (Class I) due to poaching (Sun 1996) and destruction of riparian forests (Severinghaus 1987). Even though its population was still considered very small (Fang 2005), Tawny Fish Owl was down-listed to Rare and Precious Species (Class II) in 2008, due to better knowledge of its population size (Sun 1996, Sun *et al.* 2000, 2004).

As the distribution and population size of the Tawny Fish Owl in Taiwan remained unclear, further investigation was needed to correctly assess its protection status. The aims of this study were to determine its spatial distribution and to evaluate factors affecting its distribution by identifying locations throughout Taiwan where Tawny Fish Owl had been recorded recently.

METHODS

Study area

Taiwan is a mountainous island lying between 21 and 25°N and 120 and 122°E in subtropical East Asia, about 150 km off the coast of south-east China. It is 394 km long and 144 km wide with a total area of 36,000 km². Hills and mountains with elevations higher than 100 m cover about 70% of the island (Taiwan Forestry Bureau 1995). The Central Mountain Range, with more than 200 peaks over 3,000 m in height, runs from north to south. The rivers that originate from the mountain range are short and steep with rapid currents, particularly on the east side. A lower Coastal Mountain Range is present between the east coast and the Central Mountain Range.

Forests cover 59% of the island, of which 73% is natural forest (44% of the island) (Taiwan Forestry Bureau 1995). Broad-leaved forests predominate below 1,500 m, coniferous forests above 2,500

m, with mixed forests in between. The coastal plains are much wider on the west side than on the east, and most of them have been converted to urban or agricultural areas. Only small remnants of the original riparian forests remain on the peripheral hilly areas on the west side of the mountain range, whereas most forests on the east side remain little affected because of access difficulties (Taiwan Forestry Bureau 1995). Annual precipitation is between 1,000 mm and 4,800 mm, and decreases gradually from north-east to south-west because of monsoon rainfalls and incidence of typhoons (Chiu 2006). Annual average temperature is about 25°C at sea level and 4°C at about 3,800 m (Chiu 2006).

Data collection and analysis

Tawny Fish Owl records between 1993 and 2006 were collected using the following approaches to identify locations where it occurred. First, faunal reports and the bird-sighting databases of wild bird societies were searched for records, and the collection data for Tawny Fish Owl specimens preserved in the Academia Sinica (AS), the National Taiwan Museum (NTM), National Museum of Natural Science (NMNS), and Taiwan Endemic Species Research Institute (TESRI) were examined. A total of 42 records were obtained: nine records from faunal reports, 15 from wild bird societies, two from AS, five from NTM, six from NMNS, and five from TESRI.

Second, 19 birdwatchers and 119 hunters from 27 indigenous villages located near rivers where there were no or very few records of Tawny Fish Owls were interviewed. All information indicating the presence of owls was collected, including hunting captures, sightings, calling birds, pellets, feathers, droppings and food remains. Tawny Fish Owl calls are easily distinguished from those of other owls in Taiwan (Sun 1996). Interviewees had to describe the sound of the owl clearly before each record was considered valid. As a fish-eater, the droppings and food remains of Tawny Fish Owls were easily identifiable (Wu *et al.* 2006). We obtained 52 records from the interviewees.

Third, field surveys were conducted to identify Tawny Fish Owl sites, using the same clues as above to detect the presence of owls. The sites surveyed included 15 coldwater fish farms (Rainbow Trout *Oncorhynchus mykiss* and smelt [*Osmeridae* spp.]) near mountain streams, mostly in northern Taiwan. The owls preyed on fish in the farms and often left remains, such as fish scales, bloodstains and internal fish organs, along with their own feathers, near the predation sites (Sun *et al.* 2004).

The Tawny Fish Owl has a strong territorial habit (Fogden 1973, Sun 1996, Sun *et al.* 2000). A territory of a pair of owls was

estimated to be about 6.2 km along a river and less than 550 m from the bank, derived from two territories measured by radio-tracking (Sun *et al.* 2000). In this study any owl records obtained within a 6.2 km length of river were considered to refer to a single pair, and the midpoint of the two outermost records was used to represent the territorial site.

To construct the Tawny Fish Owl's altitudinal distribution chart, the elevation of each of the owl territories was obtained by using coordinates under Identify (ArcGIS) on a Digital Terrain Model (DTM) of Taiwan (precision 40 m × 40 m). The perpendicular distance of each owl territory from the crest line of the Central Mountain Range was calculated, to illustrate how altitudinal distribution varied across the island. A 50 m interval contour map was created from the DTM by 3D Analyst, and then transformed to a 3D topographic chart in ArcScene. The 3D topographic chart was rotated to calculate the altitudinal profile of the island (between 25 and 375 km south of the northern tip of the island), as viewed by an observer standing on the south end of the island. Elevations of territories to the east and west sides of the Central Mountain Range were compared with an independent *t*-test.

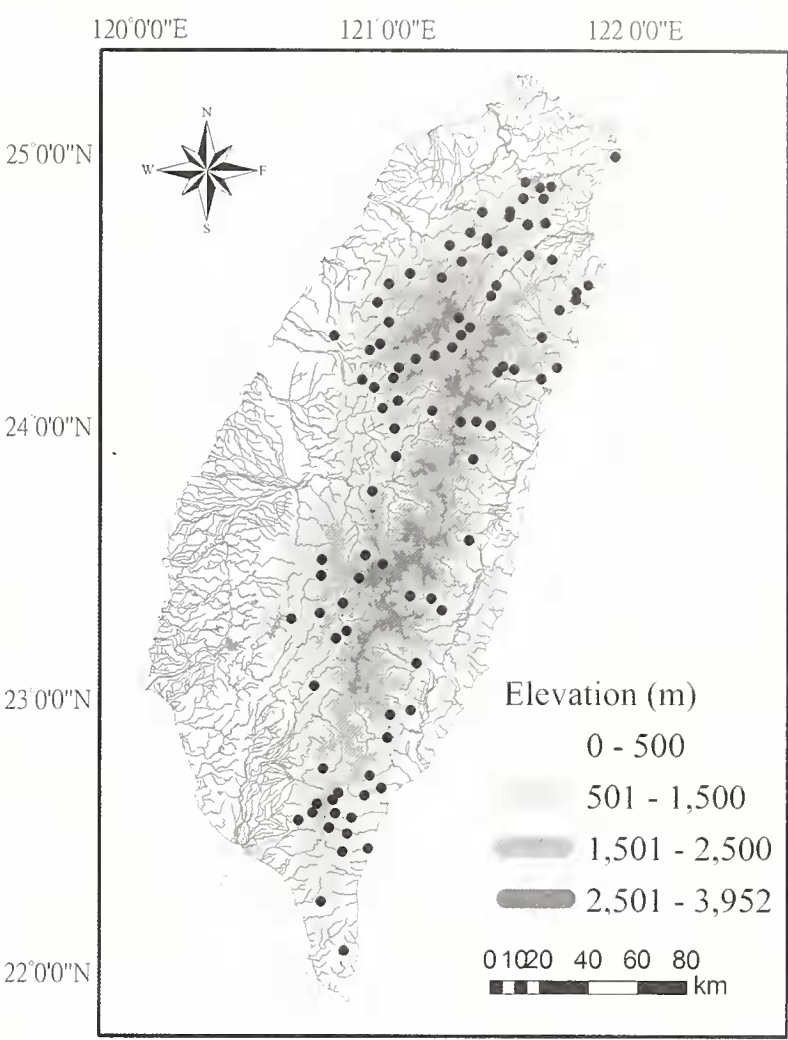
The altitudinal range of the island from sea level to 3,950 m was divided into four bands: <500 m, 500–1,000 m, 1,000–1,500 m and >1,500 m. The proportion of owl territories in each altitude band was compared with the proportion of the land area in each altitude band. A use and availability analysis (Litvaitis *et al.* 1994) was conducted using a chi-squared test and multiple simultaneous comparisons between Bonferroni confidence intervals of observed use and the proportion of land area in each altitude band. All statistical analyses were conducted with SPSS 10.0.7C for Windows with an α -level set at 0.05.

RESULTS

A total of 153 owl records were obtained. Of these, 15 museum specimens and 11 records from wild bird societies had no clear location and were excluded from the study. The 127 valid records consisted of 37 from birdwatchers, 28 from indigenous hunters, 35 from field surveys along rivers, 15 from fish farms, 9 from fauna reports and 3 from museum collections. Of these, 39 records were direct sightings of owls, 35 hunting captures or owls found dead, 28 sites with owl pellets, 17 calling birds and 8 records of feathers, food remains, droppings or other signs (Table 1).

Taking owl records found within a 6.2 km section of a river to represent single pairs, the 127 valid records indicate 91 owl territories. Two of these territories had four records and 70

Figure 1. Locations of 91 verified Tawny Fish Owl territories in Taiwan, 1993 to 2006.



territories contained only one. The territories were distributed along mountain streams in the Central Mountain Range (Figure 1). There were no records from either of the coastal plains or the Coastal Mountain Range in the east.

The altitudinal distribution of the owl territories ranged between 48 m and 2,407 m with mean 687 m and the middle 50% range between 300 m and 1,100 m (Figure 2). The distribution was skewed toward low elevations (skewness = 0.97), implying that most of the owl territories were located at lower altitudes.

The transverse altitudinal distribution of the owl territories in relation to the Central Mountain Range is shown in Figure 3. There was significant difference ($t = 3.04$, $df = 55$, $P < 0.01$) between the

Table 1. Sources and categories of 127 Tawny Fish Owl records obtained in 1993–2006 for this study. Captured birds included those caught by hunters or found dead by birdwatchers and those preserved as specimens in museums and research institutions.

Categories	Sources						Total
	Birdwatchers	Field survey	Hunters	Fish farm	Reports	Museums	
Sightings	13	13	11		2		39
Captures	2		15	15		3	35
Pellets	10	14			4		28
Calling birds	8	5	2		2		17
Feathers/ food remains	3	1					4
Droppings		2					2
Others	1				1		2
Total	37	35	28	15	9	3	127

Figure 2. Frequency distribution of the elevations of 91 verified Tawny Fish Owl territories in Taiwan, 1993–2006.

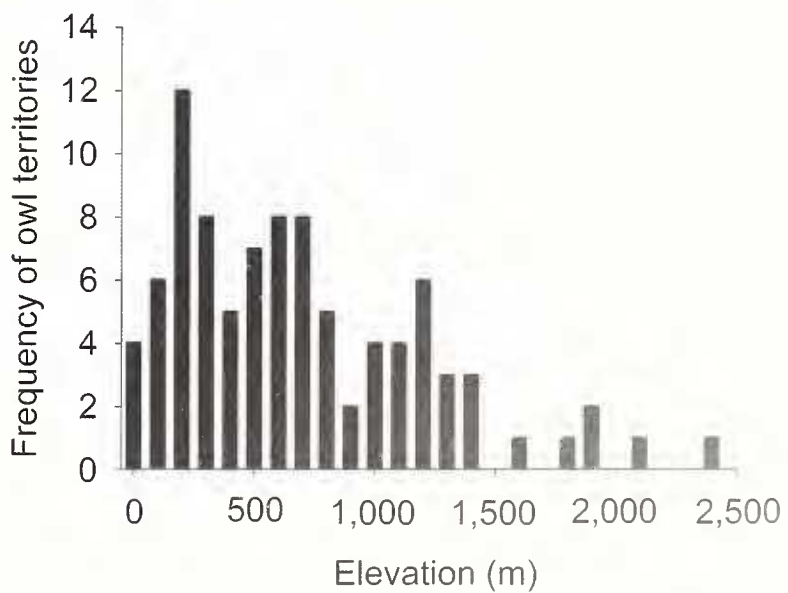
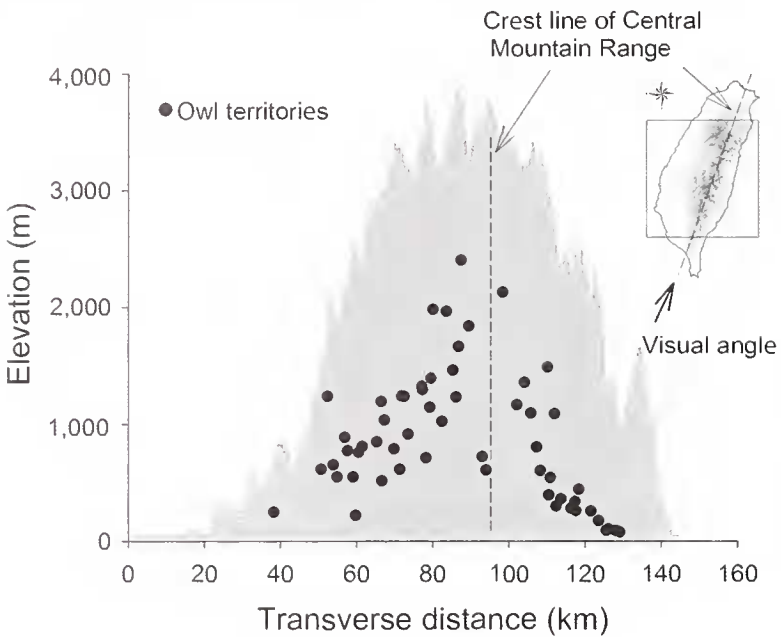


Figure 3. Altitudinal distribution of Tawny Fish Owl territories relative to the crest line of the Central Mountain Range. The grey outline shows the altitudinal profile of the island, viewed from the south end. (The vertical scale is magnified 30-fold as the elevation of Mount Yushan, the highest peak of Taiwan, is relatively small [4 km] compared with the width [144 km] of the island.)



east and west side of the mountain range. Most of the territories on the west side were above 500 m, whereas more than half of the territories on the east side were below 500 m. The former averaged 431 m higher than the latter. Territories were generally situated in deep valleys, well below the surrounding mountain ridges (Figure 3).

Tawny Fish Owls did not use the four altitude bands in proportion to the land area of the island ($\chi^2 = 41.57$, $df = 3$, $P < 0.0001$). Multiple comparisons showed that the owls appeared in land below 500 m and above 1,500 m in a significantly lower proportion compared with the land area of these altitude ranges (Table 2). In contrast, the proportion of owl territories was twice the proportion of the land area between 500 and 1,500 m, indicating that the owls selected this altitude range.

DISCUSSION

The Tawny Fish Owl mainly takes prey from streams (Sun 1996, Wu *et al.* 2006). Its upper altitudinal range may be constrained by the distribution of stream fishes (Voous 1988, Marks *et al.* 1999). In Taiwan, the highest reported elevation for stream fish is 2,400 m (Tzeng 1986, Wang 2010), which coincides with the upper limit of the owl’s altitudinal range (Figure 2). Fish abundance and diversity increase at lower elevations, for example 10 fish species occur at 1,500 m (Wang 2010) and only six owl territories were recorded above 1,500 m suggesting that fish abundance and diversity is important to the species. However, amphibians and crabs were found to be the most important prey items for Tawny Fish Owls at Sakatang Stream, eastern Taiwan (Wu *et al.* 2006), and the abundance and diversity of these taxa also increase at lower altitudes.

The occurrence of the Tawny Fish Owl was also related to the distribution of mountain streams. Streams with stable flow above 1,500 m are only found in central regions where large mountains occur. Tawny Fish Owls seldom forage in small creeks less than 5 m wide, perhaps due to food scarcity and the poor manoeuvrability of a bird with a wingspan of 1.5 m (Sun *et al.* 2000). As a result, the highest parts of the range mainly occurred around the largest mountains. The latter phenomenon was possibly enhanced by the Massenerhebung effect, which predicts that locations at the same elevation are warmer on large mountains compared to smaller ones, because the large mountains release heat more slowly (Flenley 1994).

Conversely, local differences between the altitudinal range of the owls and the surrounding mountain ridges were larger in small mountains and mountains with steep slopes. For example, the owl’s upper altitudinal limit on the east side of the Central Mountain Range, where rivers are much smaller, steeper and often dry up, was lower than that on the west side. This may partly explain why owl territories on the east side of the island were lower than those on the west side. In addition, no Tawny Fish Owls were recorded in the Coastal Mountain Range where rivers are short and small. Similarly, the owls were seldom found in streams on low mountains in the south of Taiwan. In contrast, streams in the north of Taiwan have regular water flow all year round, due to the north-east monsoon rainfalls (4,000 mm/year) (Chiu 2006), so the owls occurred further upstream, closer to the mountain ridge.

The distribution of Tawny Fish Owls in Taiwan was also influenced greatly by habitat loss due to human activities. Destruction of lowland habitat is widespread, especially on the west side of the island, due to the conversion of natural forests to farmland and urbanisation over the last 200 years. The habitat selection analysis indicated that there were fewer owls in lowland areas, even though lowlands should have more suitable streams than the hills—wider, with more reliable flow, and greater prey abundance and diversity. Most Tawny Fish Owl territories to the east of the Central Mountain Range were below 500 m, but only two owl territories were found below that elevation on the west side. The lower altitudinal limit on the west side is likely to have retreated into higher, mountainous areas, as is the case for many forest birds and mammals on the island (Liu *et al.* 2003, Shiu 2003). It is likely that the loss of natural forests below 500 m has eradicated Tawny Fish Owls from the western lowlands, since riparian natural forests are the main habitat type used by fish owls (Hayashi 1997, Sun *et al.* 2000).

Poaching is one of the most serious threats to the Tawny Fish Owl population (Severinghaus 1987) and at least 61 records of hunting have been reported since the species was legally protected in Taiwan in 1989 (Wang *et al.* 1995). Of the 28 owl records obtained from indigenous hunters, 54% were the result of poaching. Only a small proportion of indigenous hunters were interviewed, suggesting that poaching is likely to be widespread across the island.

More than 60% of the owl territories found in this study were situated outside areas protected for wildlife (Hong 2007). The lowlands are largely unprotected and those on the developed western part of the island are already deforested, therefore we recommend the establishment of a protected area for the Tawny Fish Owl along lowland streams in north-east Taiwan, where the original riparian forests still remain nearly intact (Taiwan Forestry

Table 2. The effects of altitude on territory selection by Tawny Fish Owls in Taiwan ($\chi^2 = 41.57$, $P < 0.0001$). The Bonferroni confidence intervals show that the % use of each altitude band is higher (selected) or lower (avoided) than the % availability.

Altitude band (m)	N	Use %	Availability %	Selection index	Standardised index	Bonferroni confidence intervals
<500	35	0.3846	0.5276	0.7290	0.1307	0.2571 < P_i < 0.5121
500–1,000	30	0.3297	0.1542	2.1379	0.3835	0.2065 < P_i < 0.4529
1,000–1,500	20	0.2198	0.1071	2.0521	0.3681	0.1113 < P_i < 0.3283
>1,500	6	0.0659	0.2112	0.3122	0.0560	0.0009 < P_i < 0.1310

Bureau 1995). This is possibly the only place in Taiwan where the Tawny Fish Owl range still reaches the coastline. This recommendation is in accordance with other studies that have recommended low-elevation protected areas for threatened species including Clouded Leopard *Neofelis nebulosa*, Leopard Cat *Prionailurus bengalensis*, Small Indian Civet *Viverricula indica*, Formosan Pangolin *Manis pentadactyla* and Fairy Pitta *Pitta nympha* (Liu *et al.* 2003, Chiang & Pei 2004, Lee *et al.* 2006).

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